

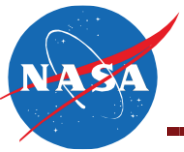
National Aeronautics and Space Administration

UAS Integration in the NAS Project Ideal Aerosmith Brief

Laurie Grindle, Project Manager

February 19, 2015





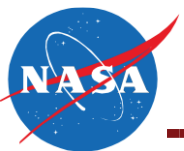
Briefing Outline

- Project History and Overview
- Integrated Test & Evaluation



Briefing Outline

- **Project History and Overview**
 - **ARMD Programmatic Structure**
 - **UAS-NAS Project Lifecycle**
 - **FAA Linkages**
 - **Content Decision Process**
 - **UAS-NAS Portfolio – Technical vs. Non-Technical**
 - **Project OV-1**
- Integrated Test & Evaluation



ARMD Programs Overview

MISSION PROGRAMS

Airspace Operations
and Safety Program



AOSP

**Safe, Efficient
Growth in Global
Operations**

**Real-Time System-
Wide Safety
Assurance**

**Assured Autonomy
for Aviation
Transformation**

Advanced Air Vehicles
Program



AAVP

**Ultra-Efficient
Commercial Vehicles**

**Innovation in
Commercial
Supersonic Aircraft**

**Transition to Low-
Carbon Propulsion**

**Assured Autonomy for
Aviation Transformation**

Integrated Aviation
Systems Program



IASP

**Flight research-
oriented, integrated,
system-level R&T
that supports all
six thrusts**

**X-planes/
test environment**

SEEDLING PROGRAM

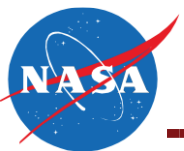
Transformative
Aeronautics Concepts
Program



TACP

**High-risk, leap-frog
ideas that support all
six thrusts**

**Critical cross-cutting
tool development**



Integrated Aviation Systems Program

Mission Program

Integrated Aviation Systems Program

Conducts research on promising concepts and technologies at an integrated system level

Explores, assesses, and demonstrates the benefits of promising technologies in a relevant environment

Conducts research into environmentally responsible aviation and unmanned system integration into the national airspace

Supports flight research needs across the ARMD strategic thrusts, programs and projects

Completes flight demonstrations

Coordinates long-term ongoing research with other ARMD programs as done by the Integrated Systems Research Program. Continues the Environmentally Responsible Aviation and UAS in the NAS projects and includes the flight test portion of the former Aeronautics Test Program.

Projects
Environmentally Responsible Aviation

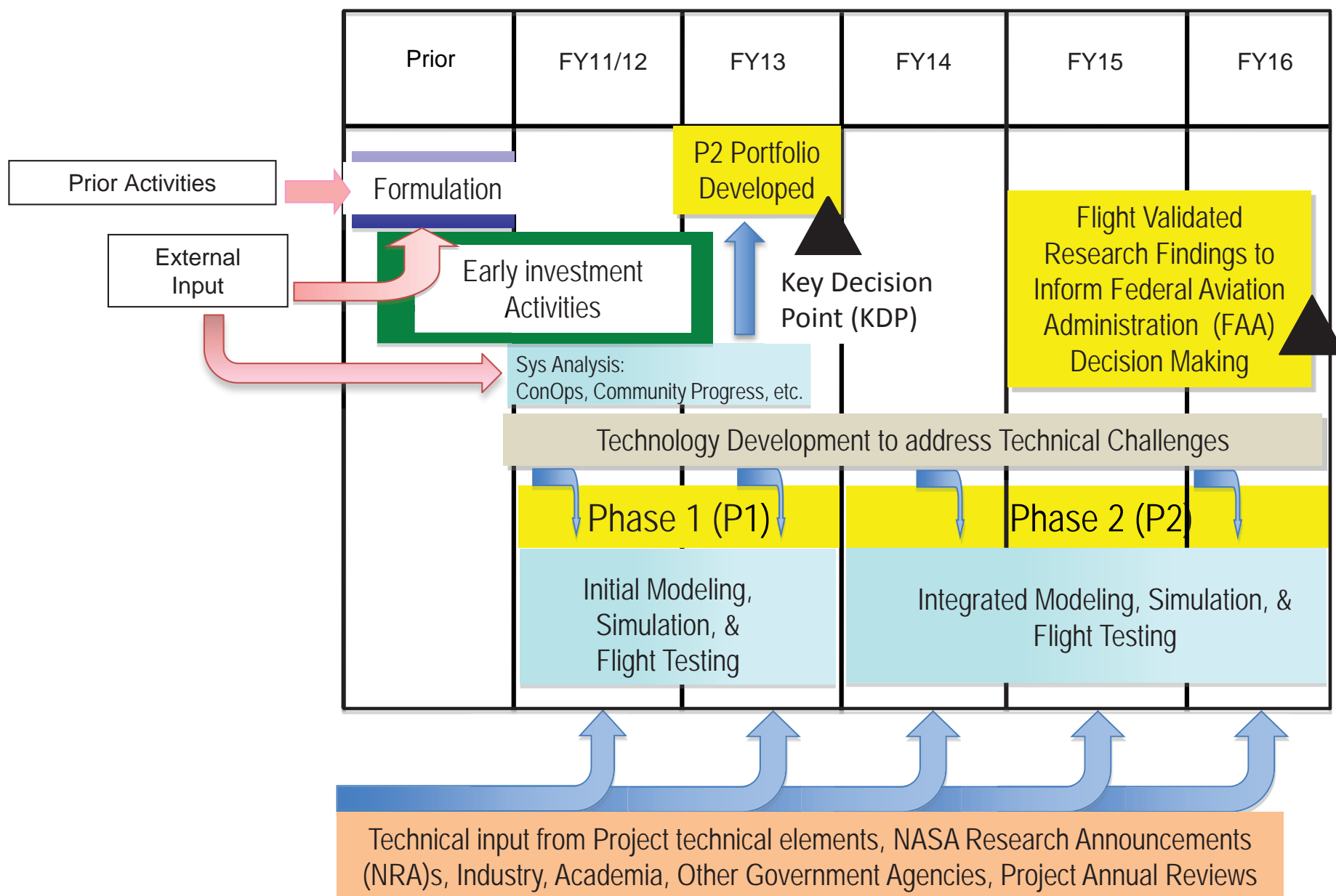
UAS Integration in the NAS

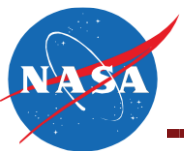
Flight Demonstrations and Capabilities





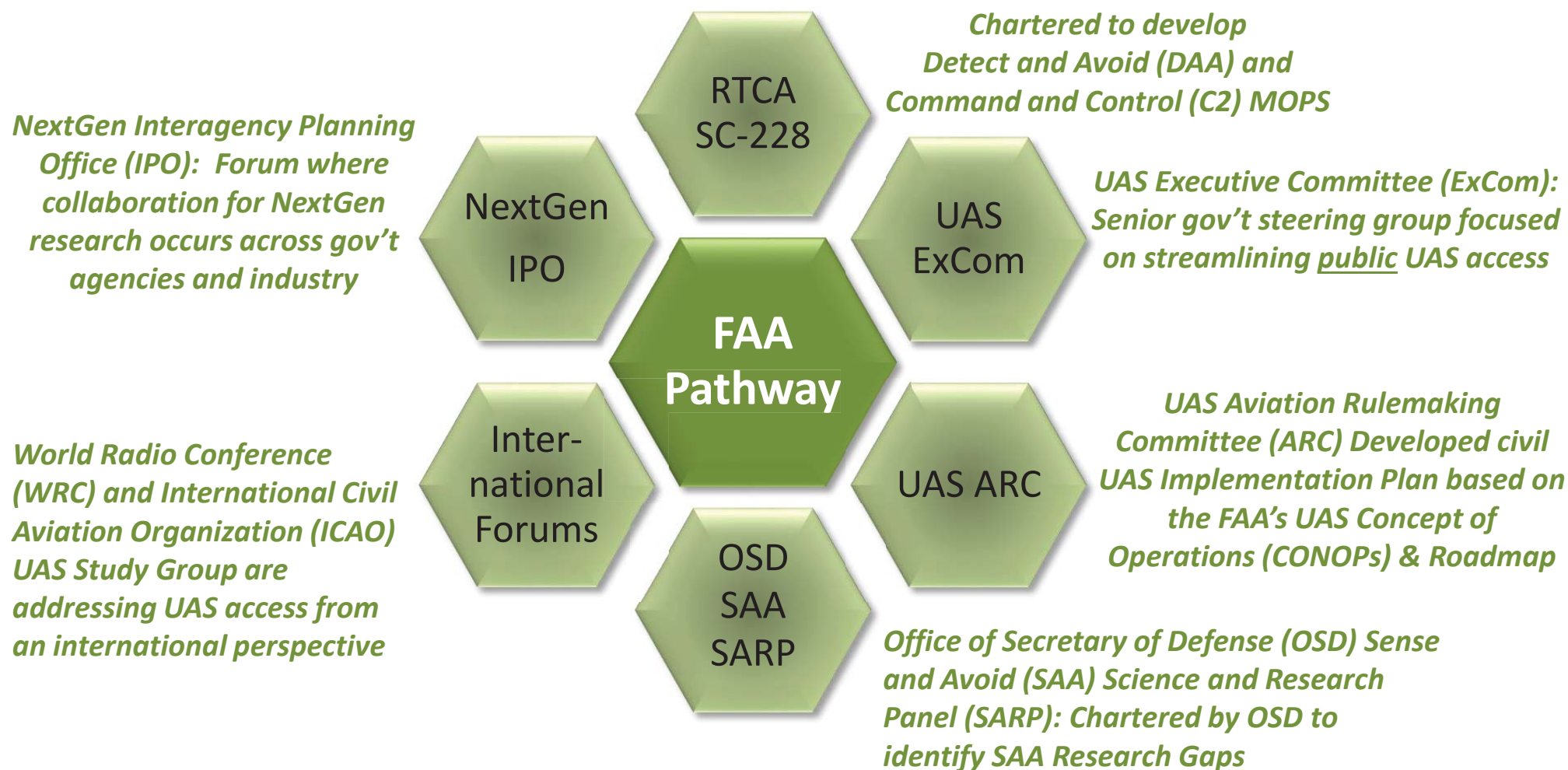
UAS-NAS Project Lifecycle



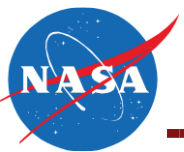


FAA Pathway to UAS Access

- The FAA is using several domestic forums, in conjunction with several international forums to lay out the pathway for their priorities and investments.

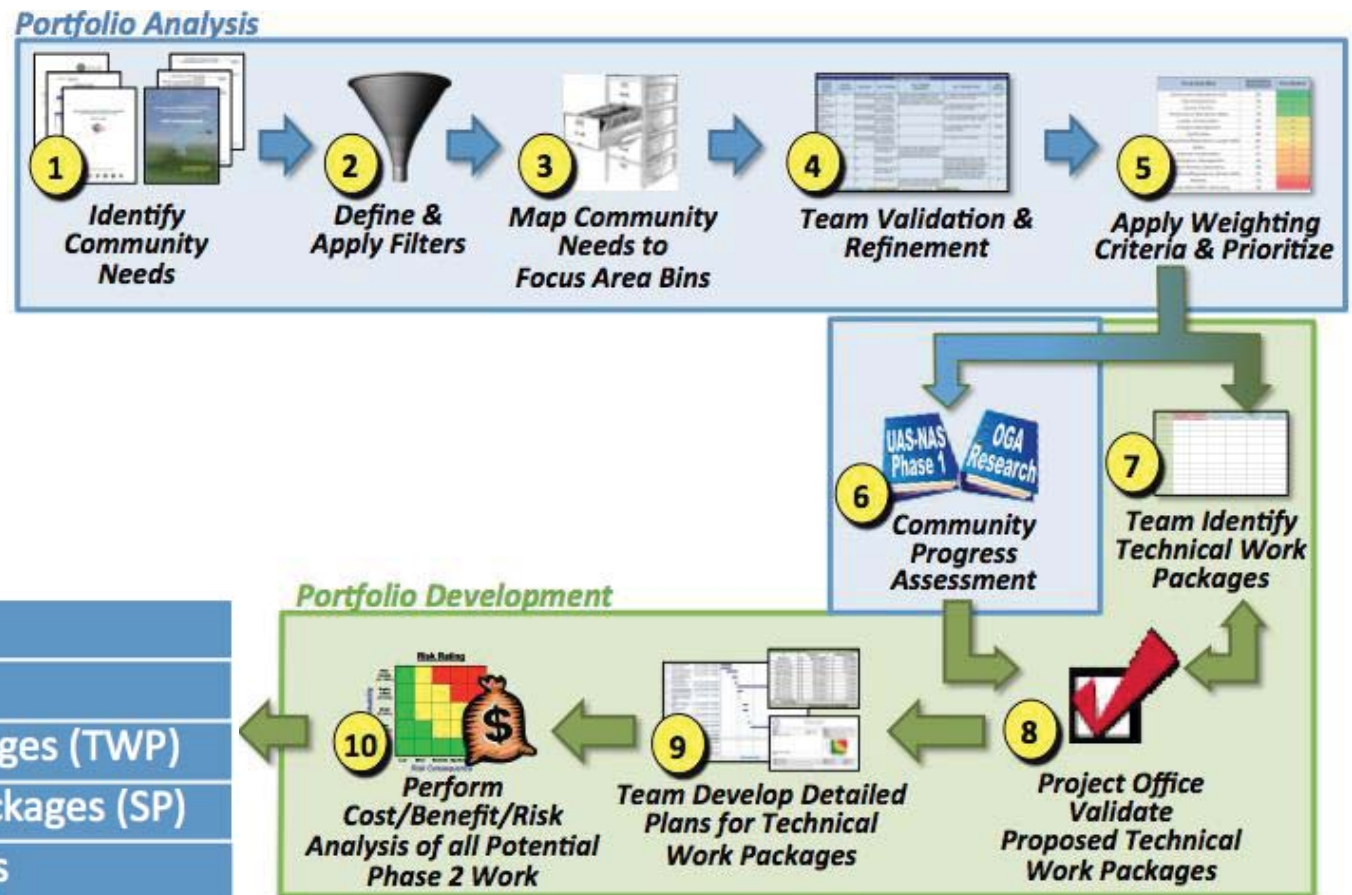


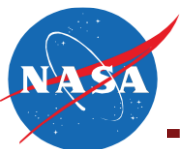
NASA has a leadership role within the domestic forums and participates in the international forums



Community Needs Influence on Phase 2 Portfolio and Technical Challenges

- Phase 2 Content Decision Process (CDP) included an evaluation of the technical needs of the UAS Community
- Resultant prioritized list, and Community Progress Assessment, of Focus Area Bins served as the foundation for Phase 2 Portfolio and Technical Challenges
- Technical challenges, Technical Work Packages, and detailed executable Schedule Packages were evaluated using a cost/benefit/risk process to determine the final portfolio





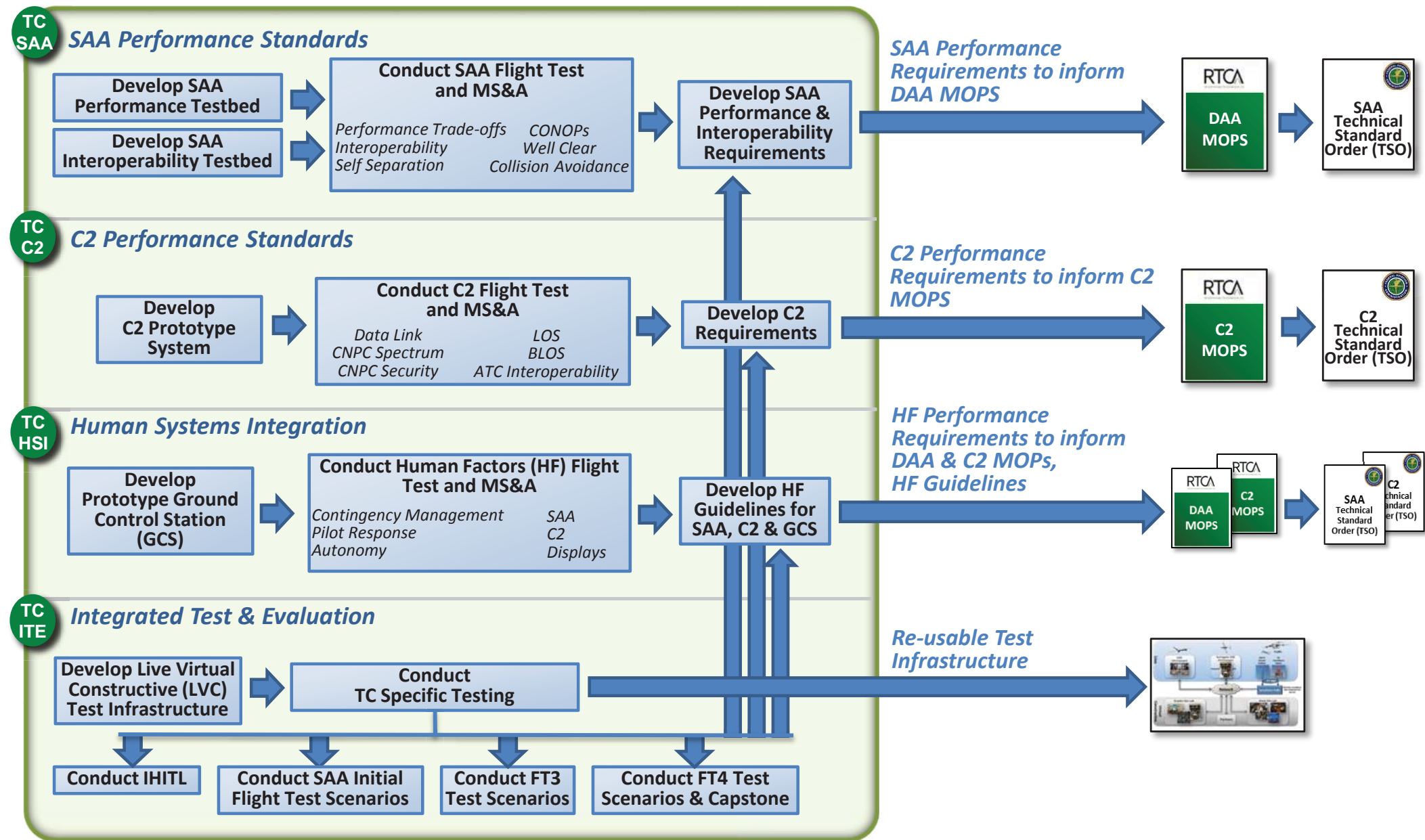
UAS Integration in the NAS Project

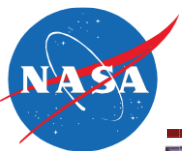
Technical Challenge Value Proposition

NASA UAS-NAS TC Project Activities

Key Products

Resultant Outcomes





Project Goal, Research Themes, & Technical Challenges

Goal: Provide research findings to reduce technical barriers associated with integrating Unmanned Aircraft Systems into the National Airspace System utilizing integrated system level tests in a relevant environment

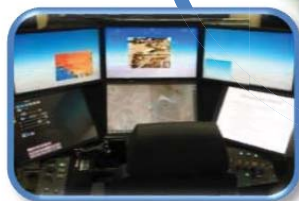
Research Theme 1: UAS Integration - Airspace integration procedures and performance standards to enable UAS integration in the air transportation system

Research Theme 2: Test Infrastructure - Test infrastructure to enable development and validation of airspace integration procedures and performance standards

TC-ITE: Integrated Test & Evaluation



TC-HSI: Human Systems Integration



Non-TC: UAS Restricted Use Certification



TC-SAA: Sense and Avoid (SAA) Performance Standards

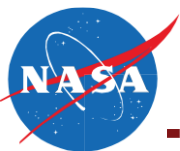


TC-C2: Command & Control (C2) Performance Standards

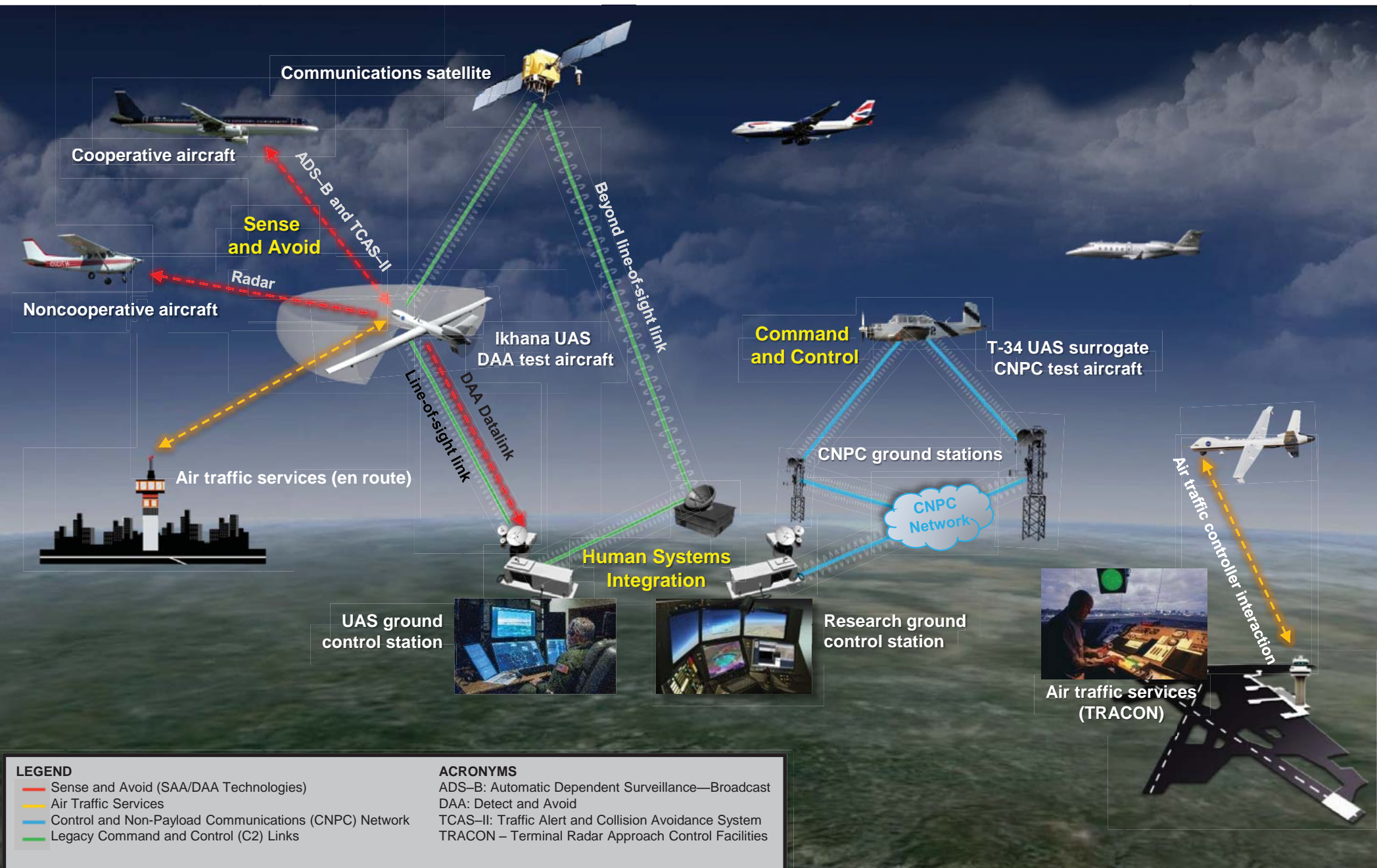


Non-TC: Small UAS Mission Support Technologies





UAS-NAS Project OV-1





Briefing Outline

- Project History and Overview
- Integrated Test & Evaluation



National Aeronautics and Space Administration



Live, Virtual, Constructive – Distributed Environment

Jim Murphy: UAS-NAS Integrated Test and Evaluation Project Engineer



RT2

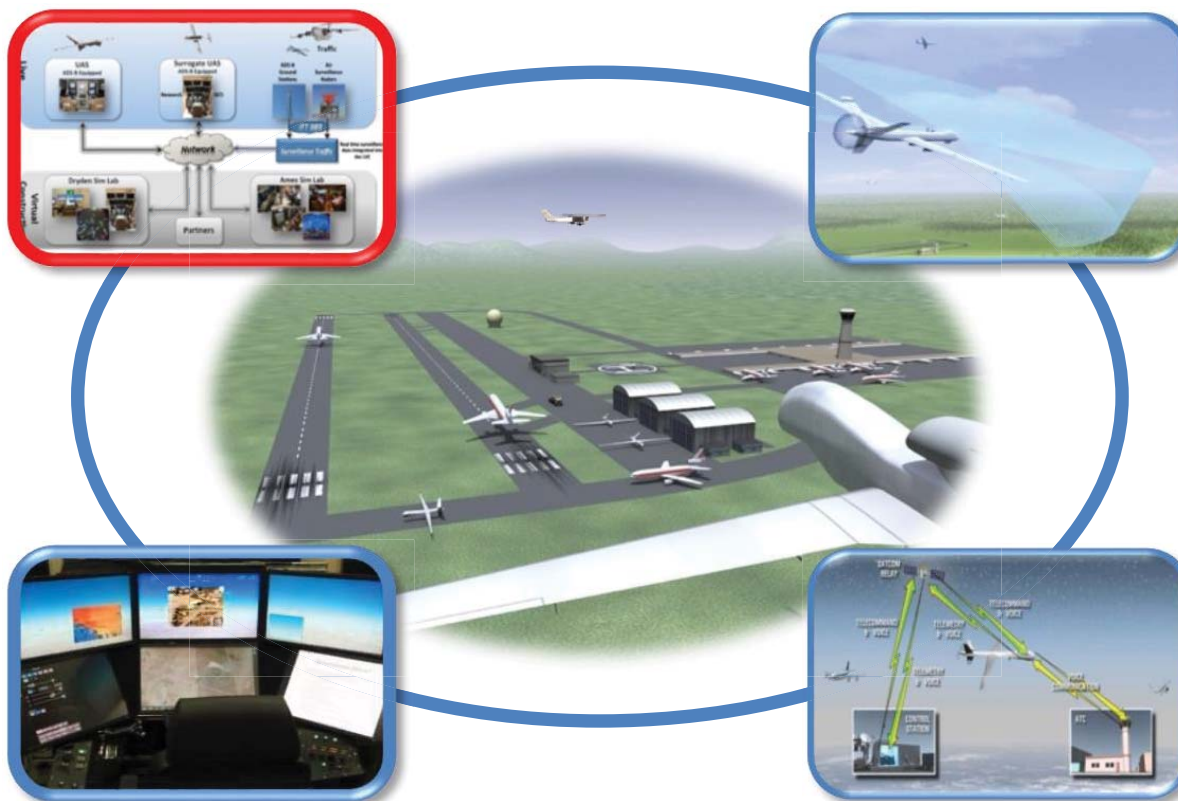
– Test Infrastructure

- Test infrastructure to enable development and validation of airspace integration procedures and performance standards.

TC-ITE

- Develop a relevant test environment for use in generating research findings to develop and validate HSI Guidelines, SAA and C2 MOPS with test scenarios supporting integration of UAS into the NAS.

TC-ITE: Integrated Test & Evaluation



TC-SAA: SAA Performance Standards

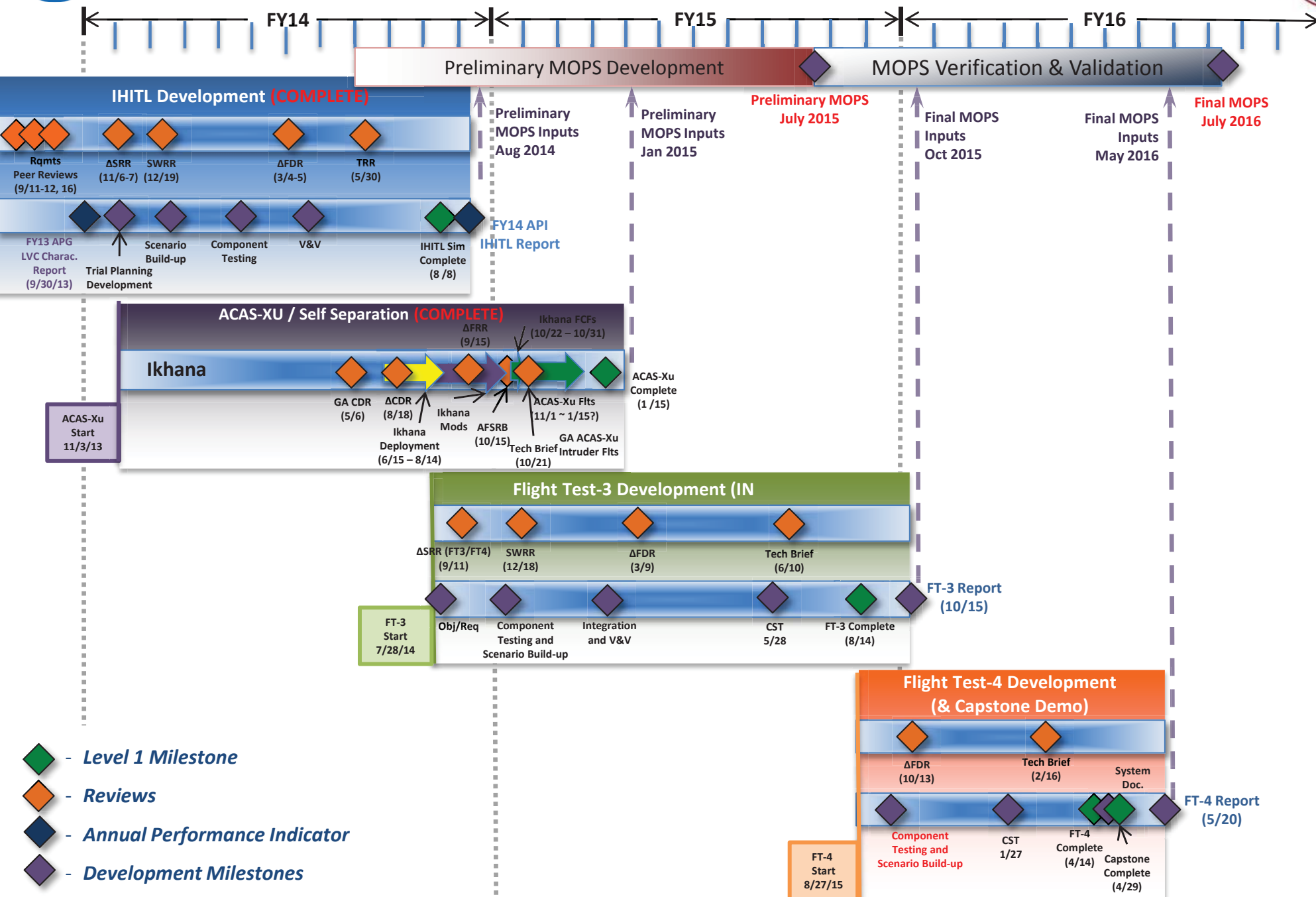
TC-HSI: Human Systems Integration

TC-C2: C2 Performance Standards



Timeline Not To Scale

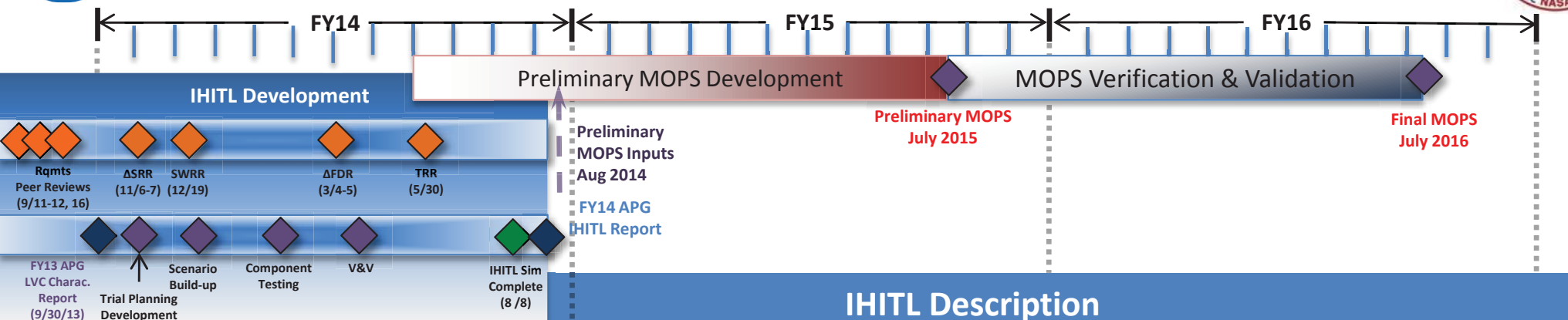
IT&E Integrated Test Flow





IT&E Integrated Test Flow

IHITL - **COMPLETED**



- **Level 1 Milestone**
- **Reviews**
- **Annual Performance Goal**
- **Development Milestones**



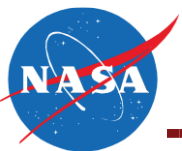
ZFW (Dallas-Ft Worth)



ZOA (Oakland Center)

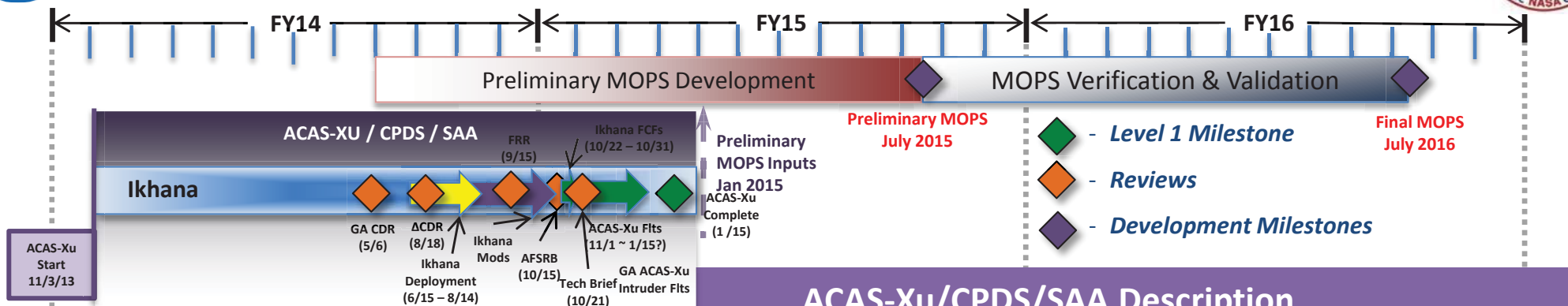
IHITL Description

Purpose	<ul style="list-style-type: none">Evaluates and measures the acceptability of algorithms and pilot guidance displays with ATC operations with increased simulation fidelity by adding CNPC time delay, a proof of concept GCS, and VFR cooperative and non-cooperative traffic.
Approach	<ul style="list-style-type: none">2 LVC configurations to be tested (Config1 & Config2)<ul style="list-style-type: none">Config1: Ames/Armstrong connectivity (ATC and Pilot test set-ups)Config2: LaRC/Ames connectivity (SAA-CA interoperability)Scenarios - Class E airspace operations near major TRACONS
Test Duration	<p>Jun – Jul 2014</p> <ul style="list-style-type: none">Config1 Test Set-up 1: ATC – 3 weeks (15 Controllers)Config1 Test Set-up 2: UAS pilots – 2 weeks (10 pilots)Config2 Test Set-up: ATC – 3 weeks (6 Controllers)
Tech Transfer	<ul style="list-style-type: none">Validated SAA, C2, HSI performance requirements and guidelinesCommunity insight into LVC Infrastructure capabilities
Project Benefit	<ul style="list-style-type: none">Validates Project modelsRisk reduction for ACAS Xu Flight Test Series and Flight Test Series 3Foundational infrastructure integrated test supports ACAS-Xu, FT3, & FT4



IT&E Integrated Test Flow

ACAS-Xu / Self Separation Flight Test - **COMPLETED**



ACAS-Xu/CPDS/SAA Description

Purpose	<ul style="list-style-type: none">Evaluate SAA Algorithm performance with actual sensor dataDemonstrate SAA CONOPS in real-world scenariosDemonstrate LVC distributed test environment
Approach	<ul style="list-style-type: none">Ikhana UAS modified with Proof of Concept DAA system (Prototype Air-to-Air Radar, SAA Processor, TCAS, ADS-B, Sensor Fusion)Multiple encounter geometries (CA and SS)
Test Duration	<p>Nov 2014 – Jan 2015 (13 flights/2 backups)</p> <ul style="list-style-type: none">Nov 2014: ACAS-Xu CA (UAS vs. Manned)Nov – Dec 2014: Self Separation (UAS vs. Manned)Dec 2014 – Jan 2015: ACAS-Xu CA (UAS vs. UAS)
Tech Transfer	<ul style="list-style-type: none">DAA CONOPs and Algorithm flight demonstrationData for validation of sensor models, well clear definition, and SS/CA interoperability
Project Benefit	<ul style="list-style-type: none">Conduct flight test risk reduction activities for FT3 and FT4Project's 1st live flight test for SAA algorithms and pilot guidance displays for real sensor data/uncertainties, real environmental factorsLVC/DE connectivity to Ikhana GCS established

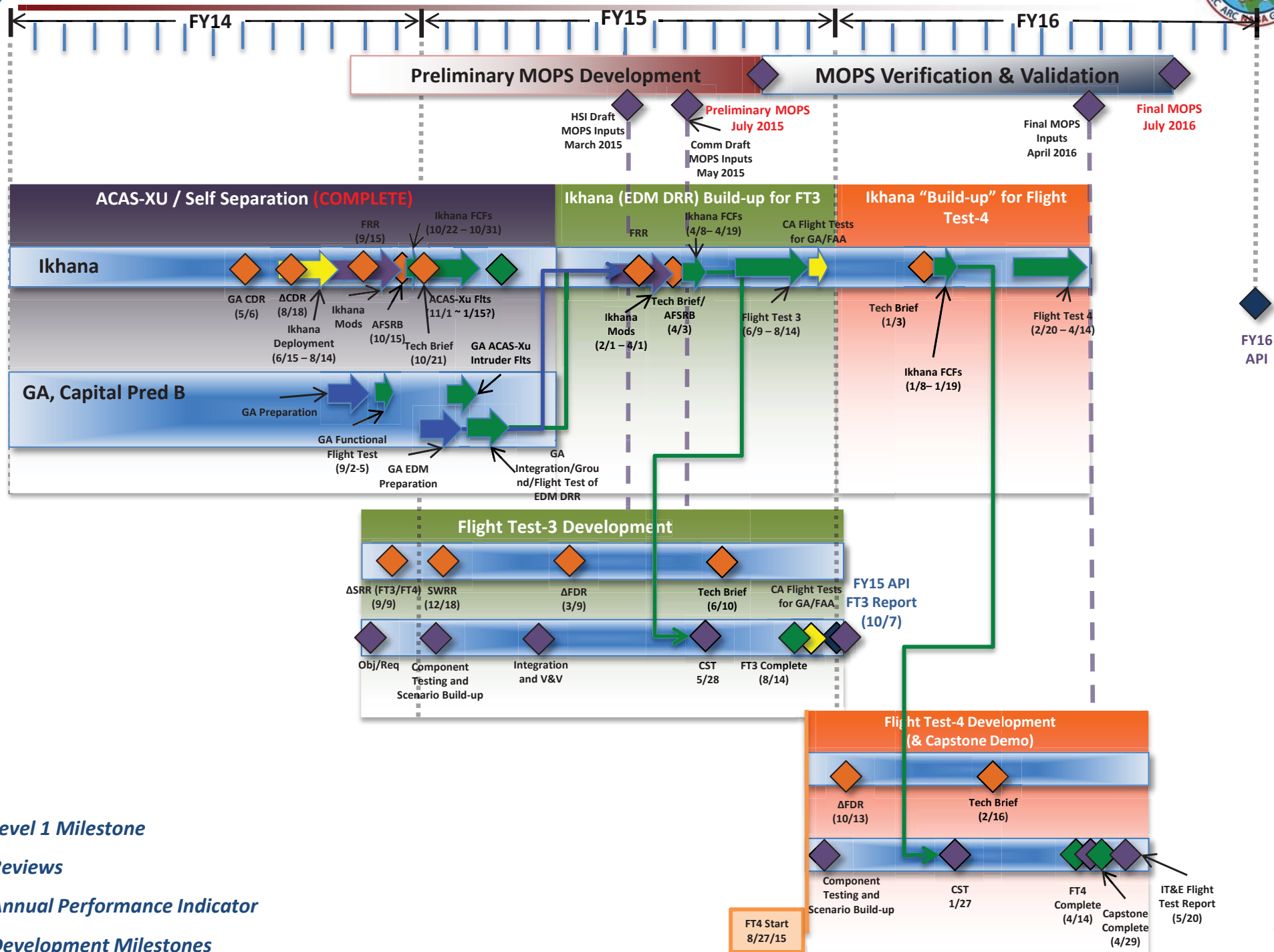


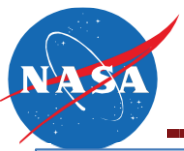
EAFB Restricted Airspace R-2515



Timeline Not To Scale

IT&E Phase 2 Flight Tests





General Research Test Objectives



IHITL
(Completed
7/25/14)

- Integrate and evaluate the state of UAS concepts and supporting technologies defined within the scope of the UAS in the NAS Project.
 - Evaluate and measure the effectiveness and acceptability of the SAA systems (algorithms and displays) to inform and advise UAS pilots
 - Evaluate and measure the interoperability and operational acceptability of UAS integration concepts in the NAS
- Characterize the test environment and identify areas of future research and development emphasis and reduce risk for the flight tests and capstone event

ACAS-Xu / SS
(In Progress)

- Conduct flight test risk reduction activities for FT3 and FT4
- Demonstrate Live, Virtual, Constructive (LVC) distributed test environment
- Demonstrate self-separation Concept of Operations (CONOPS) through real world scenarios
- Evaluate sense and avoid (SAA) algorithm performance with actual sensor data

FT3
(In Progress)

- Validate results previously collected during simulation testing (UAS CAS 2, IHITL, PT5) with live data.
- Test fully integrated UA system with components of SSI, HSI, and Comm in a relevant live test environment
 - End to end (Aircraft sensor/winds/etc. to RGCS) traffic encounter test of pilot guidance generated by SS algorithm (Stratway+, AutoResolver)
 - Conduct flight test of prototype Communication system in relevant environment
 - Collect data in support of the preliminary MOPS draft for C2 and DAA

FT4
(FY16)

- Validate C2 and DAA MOPS
 - Challenging encounter geometries with 2 or more live aircraft
 - Negotiation between UAS pilot and ATC in complex/busy airspace
 - UAS capable of autonomous SA during lost link contingency

Capstone
(FY16)

- Assess operational utility of UAS separation assurance and sense and avoid algorithms, ground control and air traffic display concepts
 - UAS line pilot flying surrogate or partner UAS
 - Mission-oriented, not test oriented

- Live: Real people operating real assets
- Virtual: Real people operating simulated assets
- Constructive: Simulated people operating simulated assets
- Distributed Environment: Brings simulation to the LVC assets increasing external partner options

T-34C UAS Surrogate



CNPC Data Link

- C2
- Voice
- H&S
- Video
- Traffic

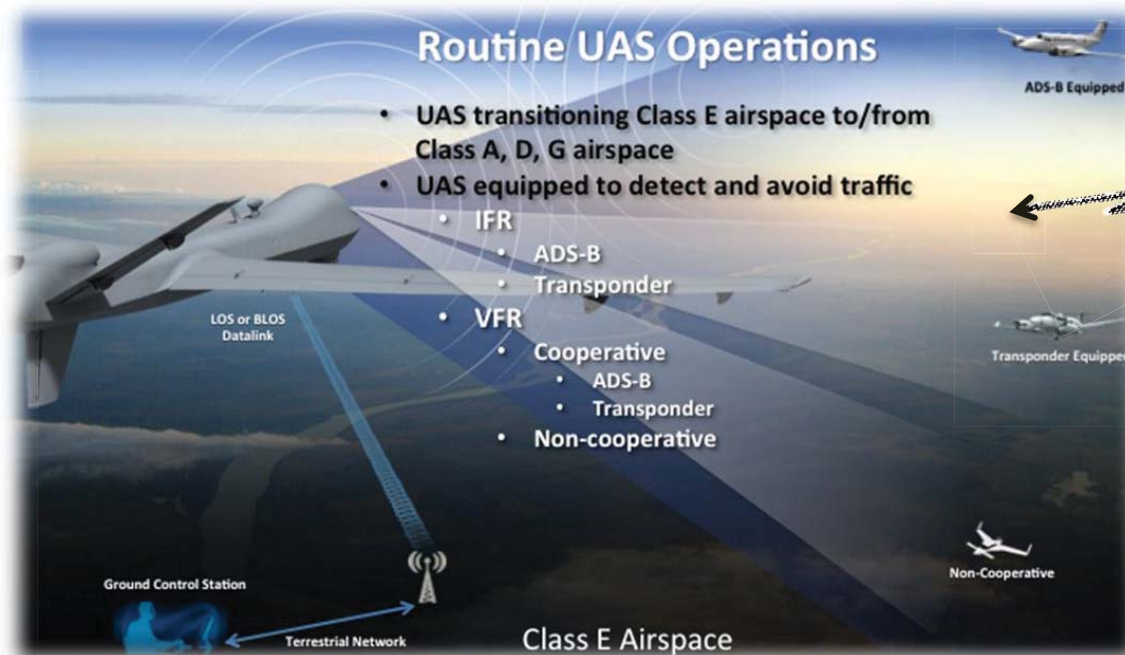
UAS Pilot



Research GCS



Displays of Proximal Traffic



Live Intruder

- ADS-B/TCAS II Equipped
- High speed

ADS-B Out

Virtual/Constructive Intruders

ATC



Target Generation

VPN

- Live
 - Ikhana (NASA's MQ-9)
 - T-34C (Manned Intruder)
 - S-3B Viking (Surrogate UAS)
- Virtual
 - Ikhana Sim
 - B747 Flight Simulator
 - Ground Control Station
 - Multi-Aircraft Control System (MACS) ATC Emulator
- Constructive
 - MACS Pseudo Pilot





Ikhana MQ-9 Predator B at NASA Armstrong

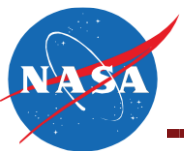


T-34C at NASA Glenn



S-3B Viking at NASA Glenn





Ikhana Simulator at NASA Armstrong





B747 Flight Simulator at NASA Ames





UAS Ground Control Station at NASA Armstrong



Lab Layout for Flight Test



Pilot Control Station Layout for Flight Test





ATC and Pseudo Pilots at NASA Ames and NASA Langley



Pseudo Pilot Control



Air Traffic Control



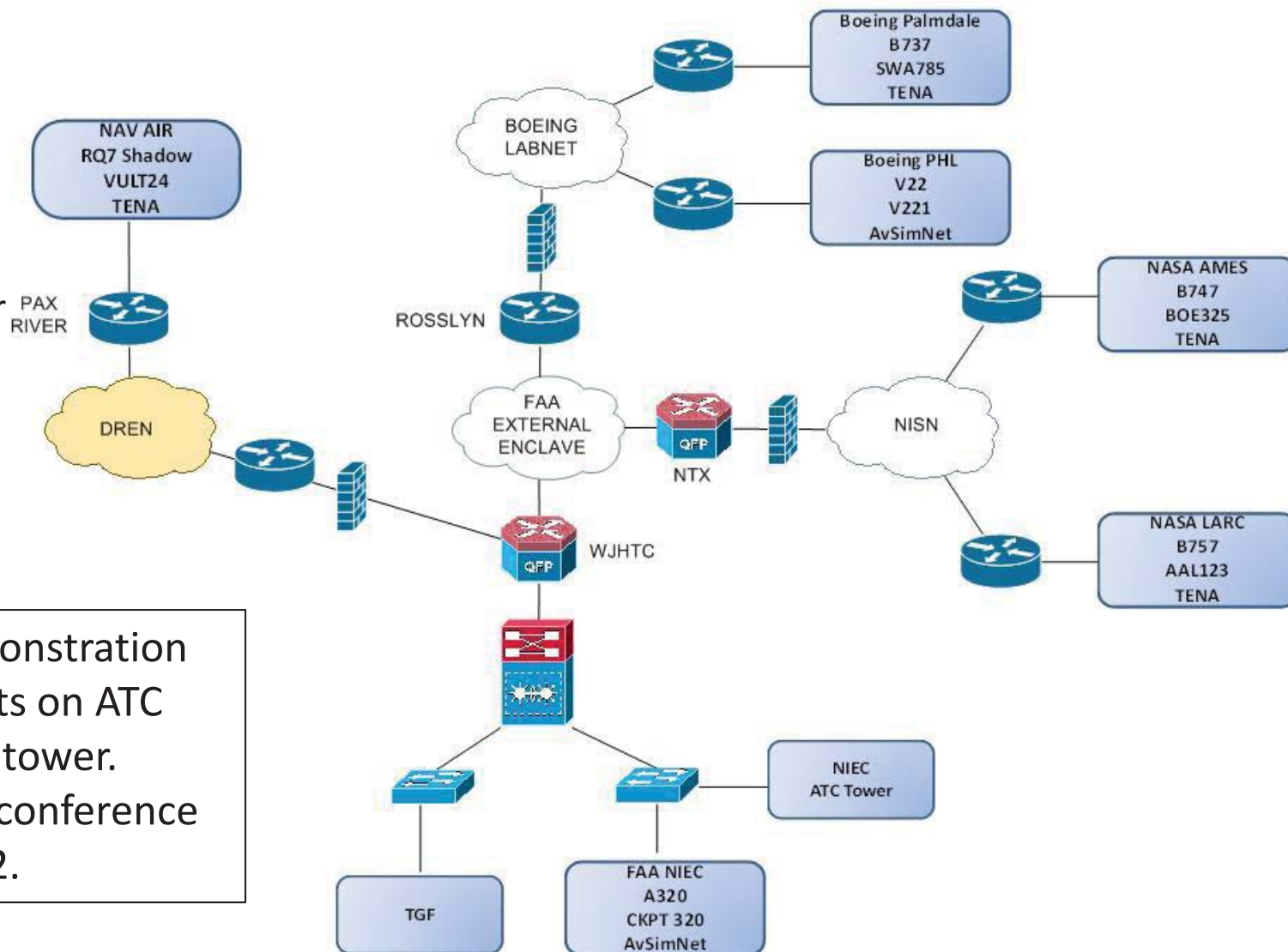


Distributed Connectivity Demonstration

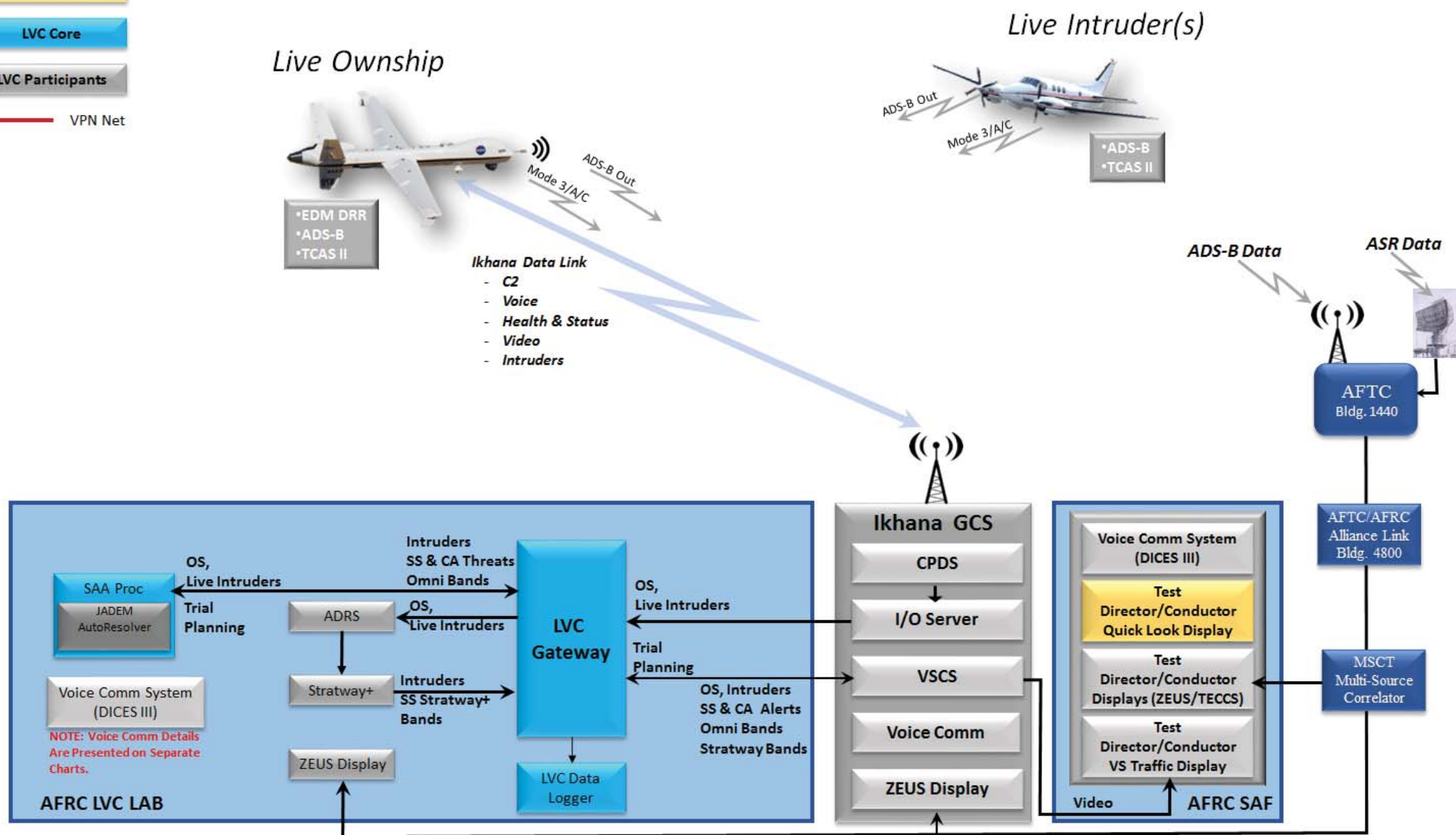
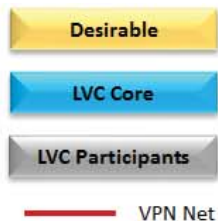


Initial test of distributed simulation capability among multiple participants

NASA Ames
NASA Langley
DoD NavAir Pax River
Boeing Palmdale
Boeing Philadelphia
FAA Technical Center

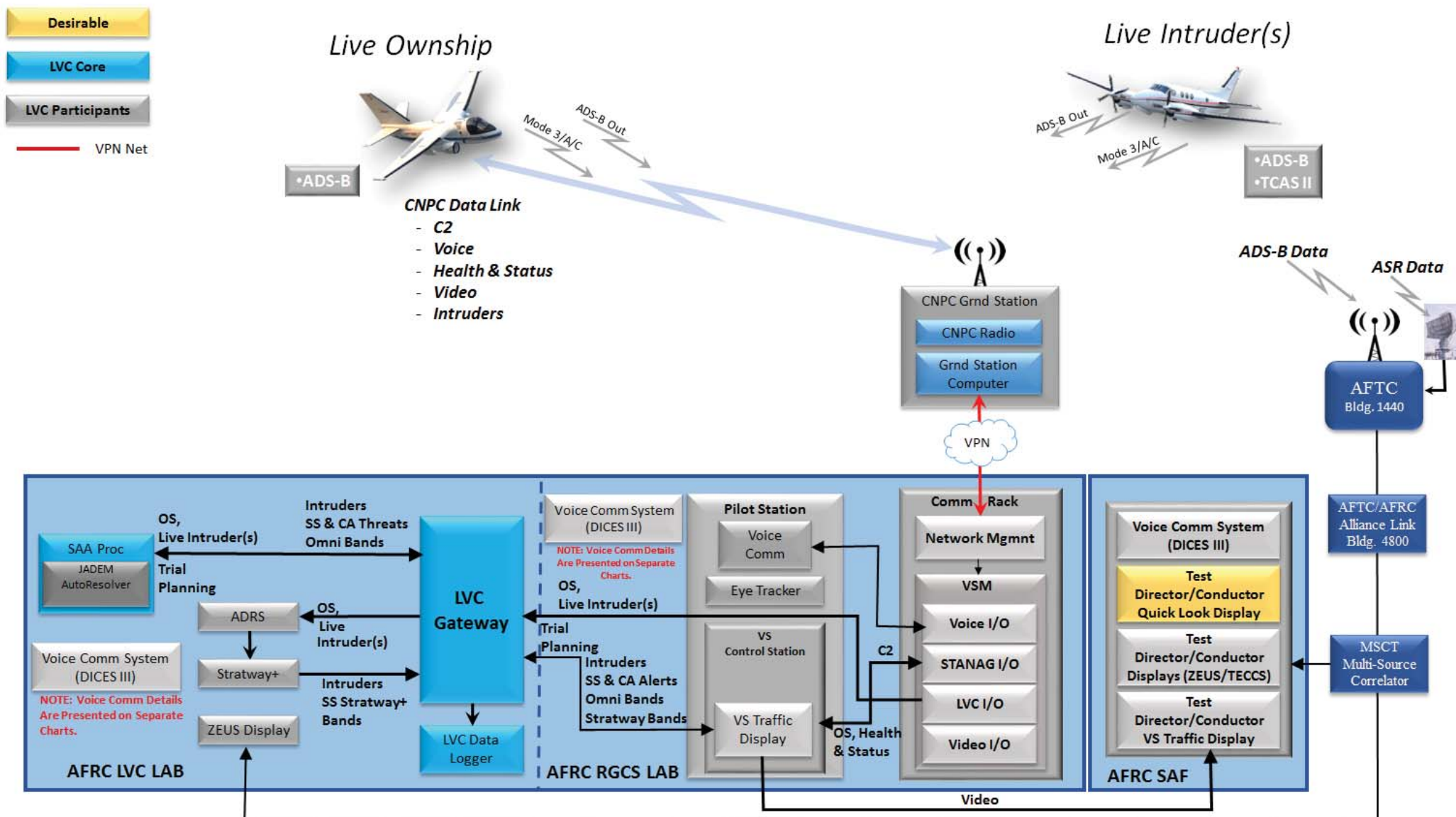


August 2012: Demonstration of simulated targets on ATC scopes and virtual tower. Presented at ITEA conference in September 2012.

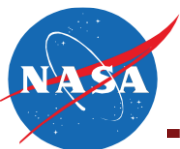




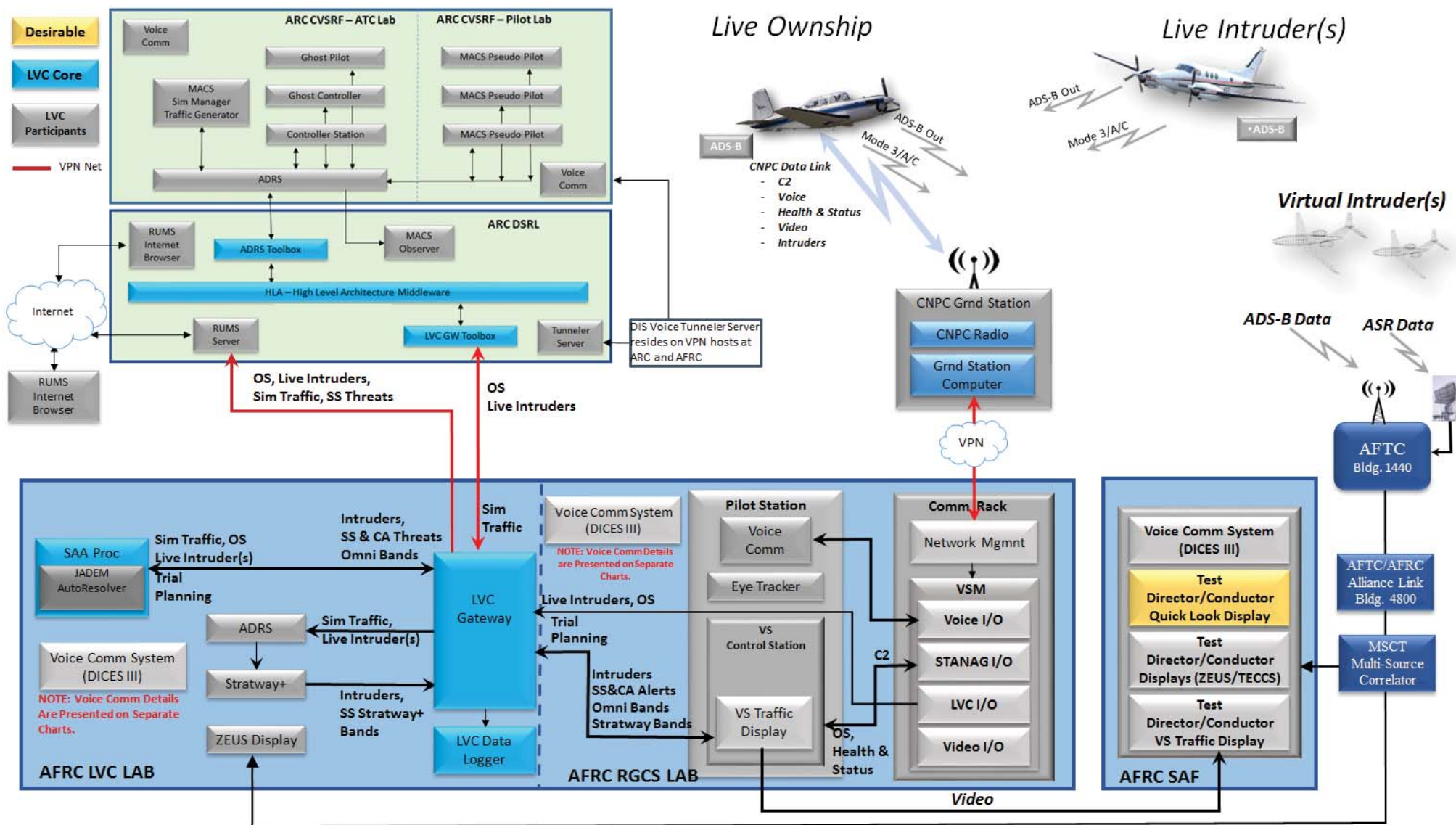
Flight Test 3: Configuration 1 (Pairwise at AFRC) – High Speed Ownship



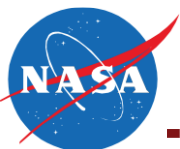
3/5/2015



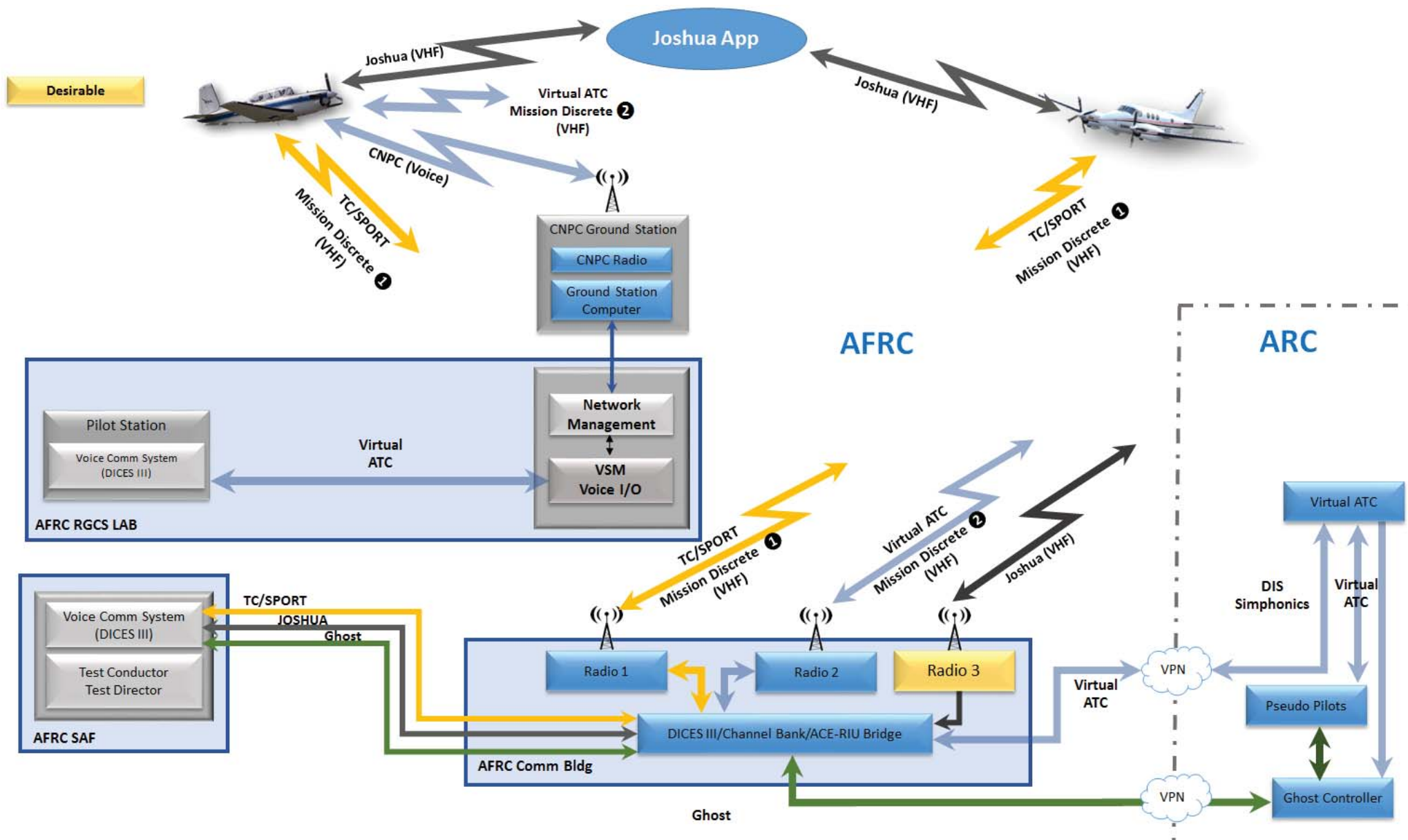
Flight Test 3: Configuration 2 (Full Mission Flights at AFRC) Surrogate UA



3/5/2015



Voice Communication Architecture – Baseline Plan FT3 Full Mission at AFRC



3/5/2015